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Hydrocleys nymphoides (Alismataceae) naturalised in New South Wales waterways

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Abstract

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau (Alismataceae) is a stoloniferous emergent/floating perennial aquatic native to the Neotropics. In Australia it is naturalised in Queensland, New South Wales, Victoria and the territory Norfolk Island. The earliest non-cultivated collection in New South Wales was made in November 1957 from Castle Hill in Sydney, and although it involved an infestation in several farm dams it was not considered an established naturalised species in that state. Since then it was reported in 1993 occurring in a dam at Murwillumbah and from 2002 specimens from naturalised occurrences have been collected from the Murray River east of Albury, near Coffs Harbour on the north coast, and on the Hacking River at Audley in the Royal National Park, south of Sydney. These findings confirm *H. nymphoides* is currently naturalised in New South Wales and the absence of any records of fruit in the Australian populations suggests the possibility it may represent a single clone or other factors required for fertilisation and seed set are absent. *Hydrocleys nymphoides,* commonly called Water Poppy, is grown as an ornamental and has the potential to escape further as an invasive weed, particularly in disturbed wetlands and waterways. Caution should be taken to avoid the introduction of fresh strains of *H. nymphoides* into Australia, especially if the current plants are sterile, as new material could increase the risk of cross-pollination and production of viable seed. A description with images of *H. nymphoides*, and notes on distribution, weed status and genome size are provided.

Introduction

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau (Alismataceae, sometimes placed in Limnocharitaceae), commonly known as Water Poppy, is a stoloniferous perennial aquatic herb native to the Neotropics where it grows in waterways and swamps (Nxumalo *et al.* 2016). In Australia, it is cultivated as an attractive ornamental in ponds and other water features, however, it has occasionally escaped and become naturalised. Aston and Jacobs (1980) reported the first naturalised Australian population near Valencia Creek township in eastern Victoria. It has subsequently been reported as naturalised in Queensland (Pennay 2017; earliest herbarium specimen in Queensland from Goosepond Creek, north Mackay, 10 Oct 1994, *R.M. Dowling WP203*, BRI; CHAH 2018), on Norfolk Island (Green 1994), and is here confirmed as being naturalised in New South Wales.

Herbarium specimens indicate that *H. nymphoides* was grown at the Royal Botanic Garden, Sydney, as early as 1899 from propagation material originally sourced from New Zealand (Aston and Jacobs 1980). The earliest non-cultivated collection in New South Wales was made in November 1957 from the Sydney suburb of Castle Hill. Although *H. nymphoides* infested several farm dams at this site it was not considered an established naturalised species in New South Wales at that time. Subsequently the species was recorded, but not vouchered, in 1993 from a dam at Murwillumbah (G. Sainty *pers. comm.* per Hosking *et al.* 2011), and from March 2002 specimens of *H. nymphoides* have been collected from a naturalised population on a lagoon on the Murray River east of Albury. In November 2015 two additional specimens were collected, from Coffs Harbour and the Hacking River, Audley. Distribution and specimen records can be found in CHAH (2018) and CSIRO (2018). This paper provides a detailed description and images of *H. nymphoides* to facilitate its recognition, and additional information on habitat, genome size, apparent sterility and invasive potential in New South Wales.

Methods

The description of *Hydrocleys nymphoides* presented is based on field observations and assessment of specimens, primarily from Australia, held at CANB and NSW. Additional data were obtained from Australian floras and other botanical treatments, including Cook *et al.* (1974), Aston and Jacobs (1980), Healy and Edgar (1980), Sainty and Jacobs (1981, 2003), Conn (1994), Green (1994), Stephens and Dowling (2002), Jacobs and McColl (2011), Richardson *et al.* (2016), and Murray (2018). Botanical regions cited for New South Wales follow those of Anderson (1961) and Jacobs and Pickard (1981).

Genome size analysis was performed on a single fresh sample of *H. nymphoides*; obtained from the Hacking River at Audley. The *Pisum* L. (Pea) genome was used as the standard and three technical replicates were measured using Flow Cytometry.

Description

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau, *Abhandlungen Herausgegeben vom Naturwissenschaftlichen verein zu Bremen* 2: 7 (1868)

Basionym: *Stratiotes nymphoides* Humb. & Bonpl. ex Willd., *Species Plantarum* 4th edn, 4(2): 821 (1806)

Type citation: Habitat in aquis ad Caracas. 2. (♂ *v.* ʃ.)

Type: n.v.

=*Hydrocleys commersonii* Rich., *Memoires du Museum d'Histoire Naturelle* 1: 368 (1815)

=*Limnocharis humboldtii* Rich., *Memoires du Museum d'Histoire Naturelle* 1: 369 (1815)

Aquatic perennial herb, with floating and emergent leaves, forming dense mats, stoloniferous, rooting along stolons at nodes, the stems trailing to several metres long. Leaves all arising from base or in clusters along stem at nodes, with lamina usually floating, ovate to broadly ovate or elliptic to suborbicular, base shallowly cordate, apex obtuse to rounded, (2.5–) 3–13.5 cm long, (2–) 3–12 cm wide, mid to dark green and glossy above, paler below, with (1–) 2–4 (–6) parallel longitudinal veins on either side of the more prominent midvein and numerous transverse interconnecting veins, glabrous, thick, spongy near midrib; petioles sheathing at base, attached at lamina margin, (3–) 10–40 (–60) cm long, to 8 mm diam., terete, brittle, transversely ribbed with externally obvious internal septa; bracts basally subtending petioles and peduncles, membranous, ovate to lanceolate, to 6.5 cm long. Juvenile leaves narrower than adult, ± narrowly elliptic. Inflorescences simple with flowers solitary in the leaf axils or in clusters of up to 6 flowers arising at stolon nodes; peduncles to 30 cm long, terete, septation similar to petioles. Flowers emergent, (4–) 5–8 cm across, short-lived, lasting 1–2 days. Sepals 3, green, shiny, narrowly ovate to elliptic, subobtuse to obtuse, coriaceous, 15–20 (–25) mm long, 6–10 mm wide, longitudinally striate, with a membranous, translucent wing around margin, persistent. Petals 3, imbricate but often opening outwards and separating, broadly obovate–rounded triangular (± fan-shaped) to rounded-rhombic, mostly 30–40 mm long, 30–50 (–55) mm wide, delicate, cream-coloured or pale yellow to yellow, sometimes white, often deeper yellow towards base, pale yellow or reddish resin/oil gland-dotted (seen as scattered minute translucent globules). Stamens numerous, outer ones sterile; anther lobes yellowish; connective reddish purple to deep maroon; filament linear, dorsiventrally flattened, reddish purple to deep maroon. Staminodes flattened, awl-shaped, same colour as filaments. Carpels usually 6 (5–8 recorded *in litt.*), 11–13 mm long, free or fused basally; stigma purple. Fruit (not observed in Australian populations) a follicle c. 15 mm long including apical beak, splitting longitudinally to release several small horseshoe-shaped seeds to 1 mm long. **Fig. 1**.

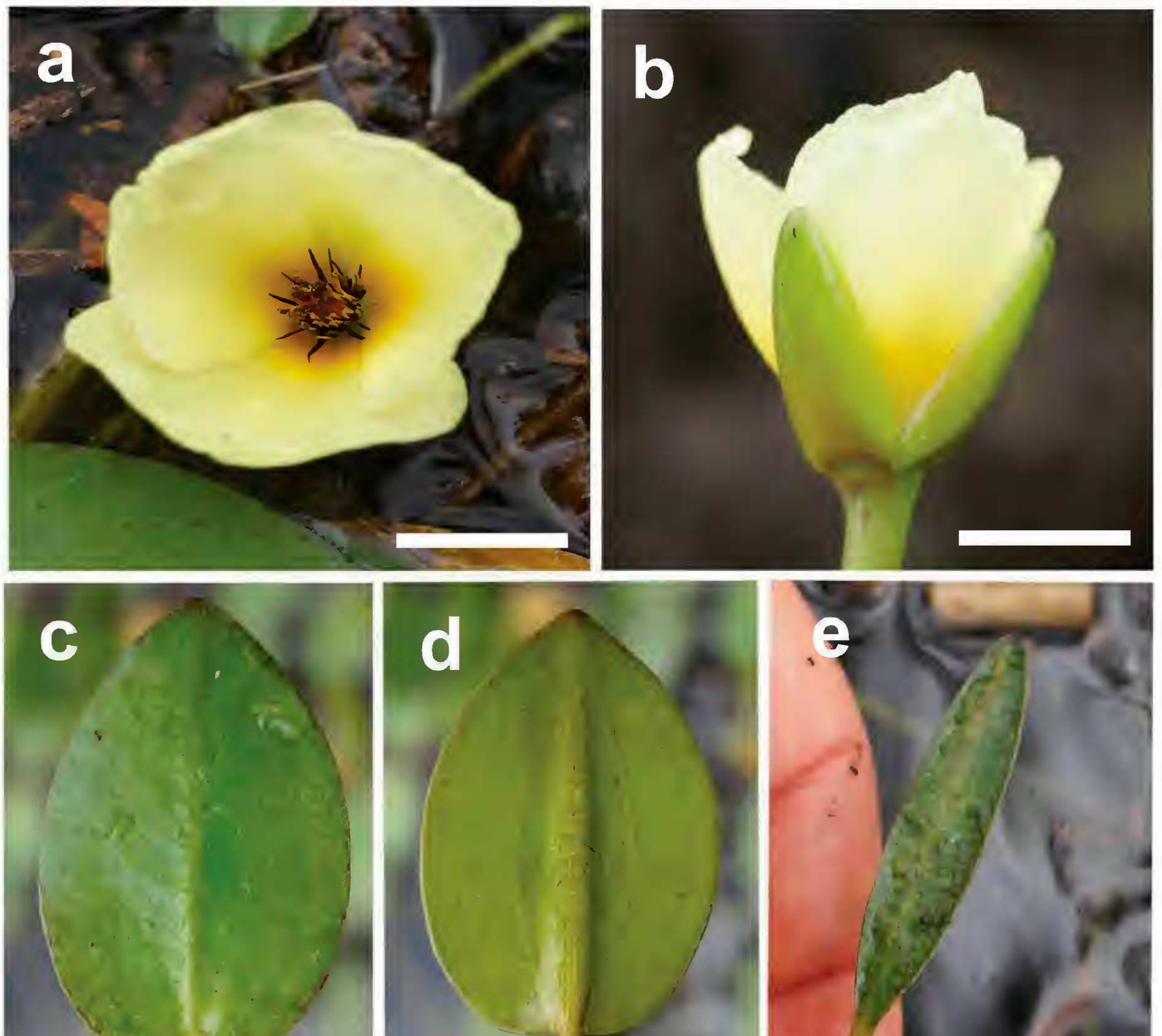

Fig. 1. *Hydrocleys nymphoides*. **a**, open flower; **b**, flower in profile; **c**, adult leaf adaxial surface; **d**, adult leaf abaxial surface; **e**, juvenile leaf adaxial surface; **f**, petiole and peduncle bracts; **g**, stolon with leaves and flowers clustered at node. Scale bars a, c–e = 20 mm; b = 15 mm; f = 10 mm. Images by R.W. Jobson (Audley Weir, N.S.W.).

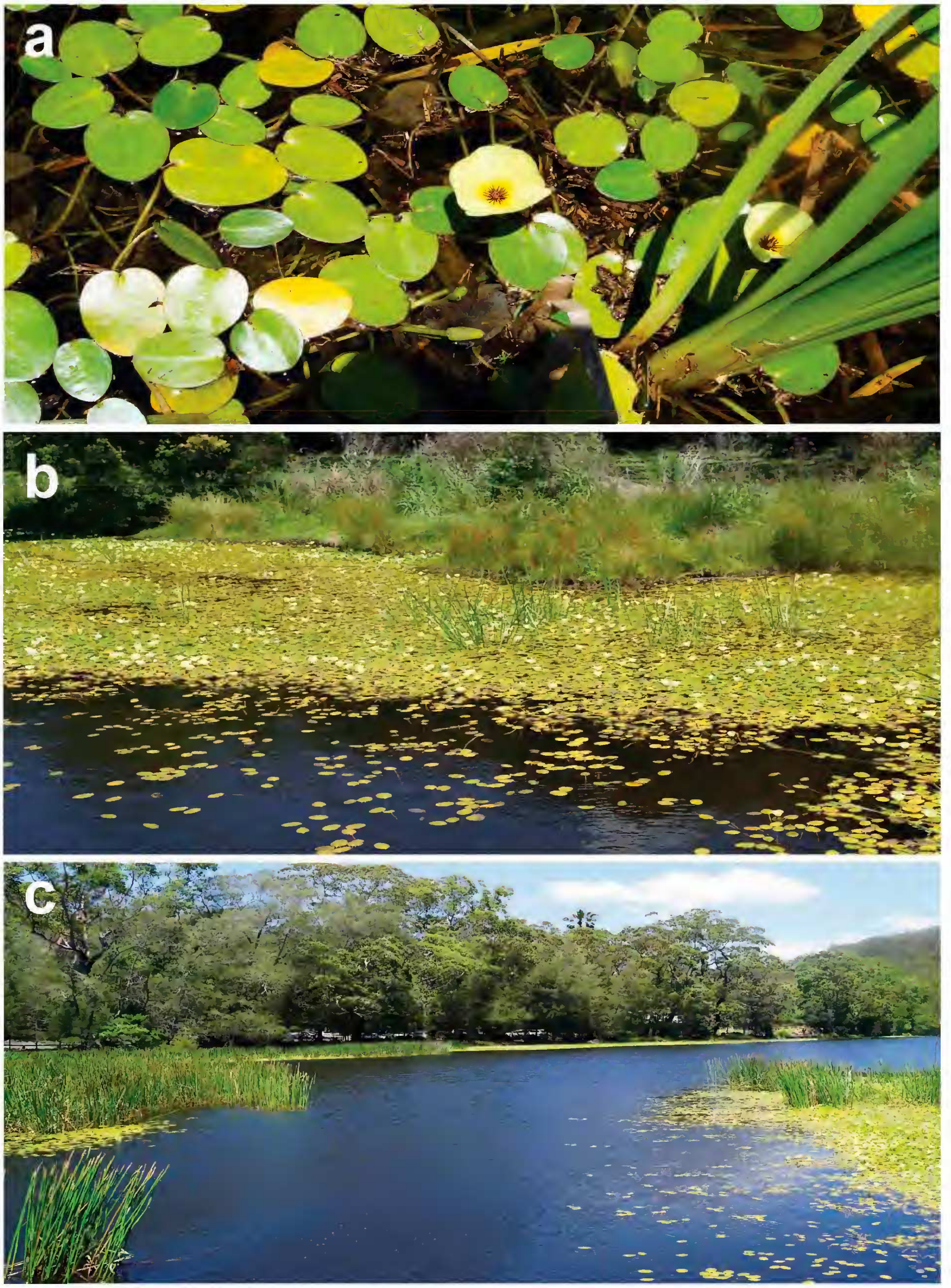

Fig. 2. *Hydrocleys nymphoides*. **a**, growth habit; **b**, dense river-side infestation; **c**, river-side habitat. Images by R.W. Jobson (Audley Weir, N.S.W.).

Phenology: flowering in warmer months, November to April.

Habitat: grows in stationary or slow-flowing nutrient-rich freshwater to 1 m deep, in swamps, creeks and other natural drainage lines, drains and dams (Sainty and Jacobs 1981). On the lower reaches of Hacking River it grows on the muddy margins of the river, above Audley weir and south for c. 2.4 km (**Fig. 2**).

Distribution: native of Central and South America, from Venezuela to Brazil to Argentina (Aston and Jacobs 1980). In Australia it is naturalised in near-coastal localities in Queensland, central and eastern Victoria, and several scattered localities in New South Wales; also recorded for Norfolk Island.

Selected specimens examined: AUSTRALIA: NEW SOUTH WALES: North Coast: near corner of Wollongba Pl. and Cavanba Rd, Toormina [near Coffs Harbour], *T. Hely s.n.*, 3 Nov 2015 (CANB, NSW 857244); **Central Coast**: Castle Hill, *collector unknown*, Nov 1957 (NSW 143693); Port Hacking River, above the Audley weir, Royal National Park, *R.W. Jobson 3122*, 27 Mar 2016 (MEL, NSW 857242 sheet, NSW 934785 spirit); **South Western Slopes**: Mungabareena Reserve, *T. Harrison 02/01*, 5 Mar 2002 (NSW 524137); Mungabareena Reserve, about 280 m from the Murray River, East Albury, *J.R. Hosking 3293 & L.K. Pearce*, 20 Dec 2009 (CANB, MEL, NE, NSW 841425, TARCH); Mungabareena Reserve, *J. Mitchell s.n.*, 15 Jan 2010 (NSW 868071). Accessions for other states (including cultivated specimens) are listed in Aston and Jacobs (1980) and provided at *The Australasian Virtual Herbarium* (CHAH 2018) and the Atlas of Living Australia (CSIRO 2018). **ARGENTINA:** Galarza, *M.M. Arbo 6250 et al.*, 16 Nov 1994 (NSW), Galarza, *M.M. Arbo 6604 et al.*, 26 Apr 1995 (NSW). **BOLIVIA:** Buena Vista, *M. Nee 40249 & I. Vargas*, 8 Dec 1990 (NSW).

Confusing species: aquatic plants are readily confused when flowers or fruit are not present. Within New South Wales, native aquatic emergent species that have floating leaves superficially resembling those of *Hydrocleys nymphoides* include Watershield (*Brasenia schreberi* J.F.Gmel.), Starfruit (*Damasonium minus* (R.Br.) Buchenau), Frogbit (*Hydrocharis dubia* (Blume) Backer) and *Ornduffia reniformis* (R.Br) Tippery & Les. However, these species can be differentiated from *H. nymphoides* based on their lack of a spongy midrib on the abaxial leaf surface (Fig. 1d) and in *Brasenia schreberi* the petiole is attached at, and the veins radiate from, the lamina centre. Marshwort (*Nymphoides* Ség.) species differ from *H. nymphoides* in having palmately veined leaves. The usually submerged juvenile leaves of *H. nymphoides* (Fig. 1e) could be confused with adult leaves of some native Pondweed (*Potamogeton* L.) species; although the spongy abaxial midrib of the former enables them to be easily distinguished.

Genome size and ploidy: the nuclear DNA content (2C-value (pg)) obtained using flow cytometric measurement for a single specimen of *H. nymphoides* from the Audley site was 25.5 pg across three technical replicates. Bennett and Leitch (1995) recorded a 2C-value for *H. nymphoides* from an undetermined source as 11.6 ($2n = 16$). This value is approximately half that of the Australian plants, which could indicate that the Australian plants are polyploids. The 2C-value reported by Bennett and Leith (1995) contrasts with a value of 22.7 pg for an assumed diploid specimen reported by Bharathan *et al.* (1994). However, Bharathan *et al.* (1994) did not count chromosomes and therefore may have unintentionally sampled a higher ploidy.

Observed sterility and dispersal: within its native range *H. nymphoides* develops fruits and seeds, and these were evident on specimens from Argentina (*Arbo 6250, 6604*) and Bolivia (*Nee 40249 & Vargas*) examined at the NSW herbarium. However, no developing or mature fruit were found during two non-systematic surveys of plants along the edges of the Hacking River (c. 30 m intervals for a distance of 500 m upstream from the weir) conducted on 27 March 2016 and 29 January 2018. All spent flowers examined were observed to be rotting off at the pedicel (RWJ, *pers. obs.*). This observation supports that of Aston and Jacobs (1980), who found no evidence of seed-set in Australia and suggested the examined populations were sterile. Various factors could potentially account for the observed sterility in Australian populations. There is the possibility that a specific vector/s geographically limited to the native Neotropical habitat is required for successful pollination. However, the close proximity of the style and anthers suggests that a generalist insect pollinator or wind could transfer pollen to the stigma surface. If a generalist insect pollinator would affect pollination then sterility cannot be explained by lack of pollinator activity as a great number of European bees were observed to visit *H. nymphoides* flowers at the Audley site (RWJ, *pers. obs.*). Aston and Jacobs (1980) suggested that the Australian populations may constitute a single clone that originated from a single introduction event (possibly from an initial introduction to New Zealand) and that a self-incompatibility system may be preventing fruit and seed development. A more detailed study of pollination systems and population dynamics is required to estimate the stability of the apparent sterility.

Hydrocleys nymphoides is stoloniferous and spreads locally by its creeping stems. In the absence of seeds, the probable mode of wider dispersal would involve stem fragments and small plantlets that are produced at the end of the growing season; these apomicts break off and float away to take root in a suitable location. Dispersal vectors are most likely to be water currents, machinery, boats, water fowl, and people.

Weed status: across much of its non-native distribution *Hydrocleys nymphoides* is a serious aquatic weed in slow moving nutrient rich waterbodies such as agricultural farm dams; it can also block drains, and water supply bodies. In natural environments it chokes out lagoons, rivers and creeks, and out-competes native emergent species (Aston and Jacobs 1980). In Australia it is an environmental weed naturalised in Victoria, New South Wales and Queensland (Randall 2002, 2017, Richardson *et al.* 2011, Romanowski 2011, Agriculture Victoria 2018 and references therein, Mifsud 2017, CHAH 2018, CSIRO 2018, NSW Department of Primary Industries 2018, Queensland Government n.d.). Nxumalo *et al.* (2016) assessed the potential risk in South Africa using the Australian Weeds Risk Assessment model (Phelong *et al.* 1999). The score for South Africa was quite low at 22, when compared to a score of 45 for New Zealand (Champion *et al.* 2014).

Although sparingly naturalised as a localised weed in New South Wales at present, *Hydrocleys nymphoides* has the potential to spread and become a more serious problem. Once established at a site the species can form extensive dense infestations, as evidenced by the population at Audley, which involves colonies scattered along a 2.4 km stretch of the river, upstream from the weir (RWJ, *pers. obs.*). Recognising the weed potential of *H. nymphoides*, it is defined as a water weed and regulated as a biosecurity risk by the New South Wales Government. Under the *Biosecurity Act 2015* it is listed as a plant "not to be sold in all or parts of NSW" (NSW Department of Primary Industries 2018).

Hydrocleys nymphoides is able to thrive in varied climates and could become an established perennial in Australia from subtropical to warm temperate regions, including areas with occasional frosts in winter (Aston and Jacobs 1980). Romanowski (2011) claims the plant is likely to expand its range if even the most conservative climate change predictions are correct, and therefore a precautionary ban on the species should be considered if the incidence of naturalised populations increases. Furthermore, if the Australian populations are all part of a single clone with an inherent inability to set seed, Aston and Jacobs (1980) cautioned against the importation of any fresh strains of *H. nymphoides* to reduce the risk of introducing new clones into the country. Such introductions could result in cross-pollination between the old and new strains and lead to the formation of viable seed. If populations were able to set seed the plant's ability to spread and become a more troublesome weed would be greatly enhanced.

Conclusion

There have been several more incidences of naturalised populations of *Hydrocleys nymphoides* occurring in New South Wales in the past decade, providing a weed alert for the State. It has the potential to become invasive in waterways and wetland habitats, with environmental, economic and social impacts. In New South Wales, *H. nymphoides* is considered a biosecurity risk with its ability to form dense infestations that can choke waterways, impacting native flora and fauna, as well as having the potential to decrease recreational values and worsen flooding (NSW Department of Primary Industries 2018). To help reduce the spread of this water weed, plants of *H. nymphoides* are not to be sold in New South Wales under the *Biosecurity Act 2015*, but the community could also be discouraged from further cultivation, especially near natural areas. Stopping the introduction of new clones into Australia would help reduce the risk of sexual reproduction and spread by seed if the current populations are indeed sterile (arising from a single clone source). Authorities and communities are encouraged to report new sightings of *H. nymphoides* and any incidence of fruit or seed development. Besides the above control measures, actions to remove weed infestations will be more effective if performed at an early stage of establishment in any particular area.

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